A RAND NOTE

Finding a New Approach to Measure the Operational Value of Intelligence for Military Operations: Annotated Briefing

E. Cesar, P. Allen, R. Eden

RAND

The research described in this report was sponsored by the United States Army under Contract No. MDA903-91-C-0006.

Published 1992 by RAND
1700 Main Street, P.O. Box 2138, Santa Monica, CA 90407-2138

A RAND NOTE

N-3551-A

Finding a New Approach to Measure the Operational Value of Intelligence for Military Operations: Annotated Briefing

E. Cesar, P. Allen, R. Eden

Prepared for the
United States Army

RAND

PREFACE

"Measuring the Operational Value of Intelligence, Electronic Warfare, and Target Acquisition (OPVIEW)" was a research project in the RAND Arroyo Center. It was sponsored by the Deputy Chief of Staff for Intelligence, Headquarters, Department of the Army (DA); the Deputy Chief of Staff for Operations, Force Development, Headquarters, DA; and the U.S. Army Intelligence Center, Fort Huachuca, AZ. The project was approved by the Arroyo Center Policy Committee in October 1989. This work was conducted in the Force Development and Technology Program of the Arroyo Center, directed by Dr. Kenneth Horn.

The purpose of this project was to develop a methodology and one or more prototype models for studying intelligence, electronic warfare, and target acquisition (IEW/TA) in an operational context; more specifically, the methodology enables the operational value of intelligence assets and activities to be expressed in quantifiable terms useful to resource acquisition decisionmakers, military planners, and battle managers.

The prototype models were designed as aids for performing policy and other analysis of key issues. The term "prototype" refers to a model that has been developed to the point that its usefulness has been demonstrated. The models can be used to help look for gaps and redundancies in current and proposed capabilities, help justify resource allocations, and seek desired mixes and employment strategies of IEW/TA assets and their communications network architectures to support future operations. One potential application of the methodology is to help build the intelligence portion of the Army five-year program.

This Note will be of particular interest to those involved in policy analysis for the Army's five-year program in support of the Army's Intelligence Master Plan (AIMP) process; in developing and applying methodology and models to assess military value, particularly the value of intelligence; and in comparing the potential contributions of IEW/TA systems, employment doctrine, and technologies in various military operations scenarios.

Throughout this project, the research team has met with key members and elements of the Army's methodology and model development community and has presented briefings and demonstrations. These audiences have included representatives from the offices of the Deputy Under Secretary of the Army

(Operations Research), the Deputy Chief of Staff for Operations and Plans, the Deputy Chief of Staff for Intelligence, the U.S. Army Intelligence Center, the Training and Doctrine Command (TRADOC), the Combined Arms Command, the Intelligence and Security Command, the Army Materiel Systems Analysis Agency, the TRADOC Research and Analysis Center, the U.S. Army Intelligence Agency, the Joint Tactical Fusion Office, the U.S. Army Laboratory Command, the Army Research Office, and the Air Defense Artillery Center and School.

THE ARROYO CENTER

The Arroyo Center is the U.S. Army's federally funded research and development center (FFRDC) for studies and analysis operated by RAND. The Arroyo Center provides the Army with objective, independent analytic research on major policy and organizational concerns, emphasizing mid- and long-term problems. Its research is carried out in four programs: Strategy and Doctrine; Force Development and Technology; Military Logistics; and Manpower and Training.

Army Regulation 5-21 contains basic policy for the conduct of the Arroyo Center. The Army provides continuing guidance and oversight through the Arroyo Center Policy Committee (ACPC), which is co-chaired by the Vice Chief of Staff and by the Assistant Secretary for Research, Development, and Acquisition. Arroyo Center work is performed under contract MDA903-91-C-0006.

The Arroyo Center is housed in RAND's Army Research Division. RAND is a private, nonprofit institution that conducts analytic research on a wide range of public policy matters affecting the nation's security and welfare.

Lynn E. Davis is Vice President for the Army Research Division and Director of the Arroyo Center. Those interested in further information about the Arroyo Center should contact her office directly:

Lynn E. Davis
RAND
1700 Main Street
P.O. Box 2138
Santa Monica CA 90407-2138

SUMMARY

This Note documents the final executive-level briefing of a project called "Measuring the Operational Value of Intelligence, Electronic Warfare, and Target Acquisition (OPVIEW)". The purpose of the OPVIEW project was to develop and apply innovative analytic tools for quantifying the operational value of IEW/TA assets and activities. It was expected that such tools would have applications to a broad range of analyses regarding military intelligence capabilities. In particular, the tools were intended to be capable of supporting the Army Planning, Programming, Budgeting and Execution System (PPBES), which produces a prioritized list of assets for Army acquisition.

The innovative feature of the OPVIEW project was that it attempted to relate IEW/TA results to the operational commander's decisionmaking. The OPVIEW analytic tools accept as inputs both the commander's information requirements and the IEW/TA collection results. They also provide a way to track how collected information affects decisions about current plans and conduct of operations. The outputs of the models represent the effect or "value" of IEW/TA in this sense.

The project developed three analytic tools: a methodology for relating commanders' requirements to collection results and two models that employ the methodology. The "static" model provides an aggregate assessment of the capability of specified systems and system packages to meet commanders' information needs in specified scenarios. The "dynamic" model is more detailed and broader in scope: It assesses the impact of intelligence collection on commanders' decisionmaking over the course of an operation from initial planning to its conclusion. All three tools depend fundamentally on subjective-judgment data, but these data are systematically developed using experts in operations planning, intelligence collection and production, and analysis. The data are predicated on basic physical laws and the previously measured performance characteristics of IEW and other systems modified by environmental, survivability, and other conditions in operational settings.

The OPVIEW models do not attempt to "certify" the validity of the data used with them. OPVIEW's merits should be judged primarily on the models themselves and the way they organize, present, and help manipulate data (from whatever source) for performing analysis, and not on the databases that presently reside in them. Since they are in table form they can be readily changed.

THE OPVIEW METHODOLOGY

The purpose of the OPVIEW methodology is to provide a system for measuring all information requirements and the capabilities of all intelligence collection systems on a common scale. A common scale not only permits requirements to be linked readily to collection results, but also permits different combinations of collection means to be compared.

The methodology uses a taxonomy of eight basic intelligence functions that was developed from an examination of over 300 PIRs (priority intelligence requirements). The functions are to detect (i.e., to detect an enemy unit), to locate generally, to locate precisely, to classify, to identify, to track, to acquire, and to assess operational capabilities (e.g., after attack). All information requirements and all collection results can be arrayed against this single framework. Coverage and timeliness requirements can also be associated with each function.

Each IEW/TA asset can be scored according to its ability to meet the coverage and timeliness requirements for the eight functions. These scores are expressed in two measures, the first expressing the full designed capability of the asset under ideal conditions and the second expressing the expected capability of the asset under specified operational conditions. The first measure is called the collection probability factor (CPF) and the second is called the conditional collection probability factor (CCPF). CPFs and CCPFs are difficult to construct: Operational and test data can be drawn on, but in large part these scores must represent subjective (albeit expert) judgment regarding the capability and performance of an asset. Several methods are available for improving the quality of such judgments, and they should be used in conjunction with the OPVIEW methodology to develop high-quality inputs.

THE STATIC MODEL

The second analytic product of the OPVIEW project is a static model that employs the OPVIEW methodology to assess the capability of alternative collection systems and system packages in specified operational scenarios. The model is called "static" because it does not represent time or the effects of time in its representation of the scenario and its assessment of the intelligence capabilities. For example, it can assess the capability of a specified system package to meet the requirements of a Korean combat scenario, but it cannot provide assessments at different points in time through the course of the scenario. (This capability, which entails a detailed simulation of the operational scenario, is provided by the OPVIEW dynamic model,

described below.) This means that the static model represents only the capability of intelligence assets to meet the commander's requirements, not its impact on subsequent decisionmaking.

The model is very quick running and is implemented on Microsoft Excel spreadsheets run on a Macintosh computer. It was designed to be easily understood to facilitate interaction among its multiple potential users—analysts, military intelligence experts, operational planners, and resource allocators.

The static model was developed and applied to support the Army's MI (Military Intelligence) 2000 Relook Study. In that role, it was used to analyze future Army intelligence capabilities in eleven scenarios (both noncombat and combat). These results were used to develop both minimum and preferred lists of systems for input to the Army PPBES. For items on the preferred lists, it was also possible to determine the added value (averaged across the eleven scenarios) of acquiring each one above the number recommended on the minimum list.

THE DYNAMIC MODEL

The third analytic tool developed by the OPVIEW project is a dynamic model that simulates the contributions of IEW/TA assets and activities to operational outcomes throughout the course of a specified scenario. Its scope ranges from mission planning to operational outcomes. It represents the effects on collection due to terrain, weather, and countermeasures. Its most innovative feature is that it models commanders' decisionmaking (on both sides), including selection of alternative courses of action based on intelligence results.

The static and dynamic models can be used to complement one another in an analysis. The static model, since it is fast-running and less detailed, can be used to analyze many scenarios relatively quickly. The dynamic model can then be used to analyze the most interesting cases in more detail.

The dynamic model is used in the following way: First, one selects a region, conflict state, opposing forces, missions, and the objectives, plans, and PIRs for each side. Next, one selects the types of systems to be examined, their mix and quantities, and how this information will be employed in support of the existing plan. These data are fed into the model, which then simulates the operation, including the intelligence, decision, and assessment functions. Depending on the purpose of the analysis, several runs with alternative inputs (different sensors, plans, decision criteria, etc.) may be required.

The dynamic model contains three major submodels: an intelligence submodel, an operations submodel, and the decision submodel. The most innovative of these is the decision submodel. Throughout the course of a simulation, this model accepts inputs from the intelligence model regarding intelligence collection results and then feeds operation management decisions into the operations submodel. The analyst can specify decision points in the operation plans, where the (simulated) commander must make a decision based on intelligence collection results, and can specify decision criteria. These capabilities permit the analyst to model alternative command styles—cautious, aggressive, etc.—on both sides. For example, a plan might include the decision criteria "withdraw when the force ratio is too high," where "too high" is specified in terms of at least one information requirement.

Like the static model, the dynamic model is designed to be easily understandable by nonanalysts. Although complex, its code is written in an English-like language called RAND-ABEL™[1] that is understandable to nonprogrammers with very little training. This permits the code to be reviewed by experts in operations planning and military intelligence.

For additional analytic ease, the outputs of the dynamic model can be viewed on full-color computer graphic displays.

PROJECT STATUS

The OPVIEW project ended in 1992 after four years of research. In that time it developed the OPVIEW methodology, a static model, and a prototype dynamic model. The static model was transferred to the Army with the final report of the effort in support of the MI 2000 Relook Study. The prototype dynamic model—which demonstrates the proof of principle but is not yet a production model—was transferred to the Army with the OPVIEW final report.

Although the prototype model has been demonstrated to connect, end-to-end, all of the submodels and provide results for analysis, it is not yet sufficiently robust to perform extensive sensitivity analysis. When the model is to be used for actual studies, scenarios, operational plans, doctrine, rules, and environmental and system data will have to be provided. Requirements and procedures for this are described in the final report.

A concept for the verification and validation (V&V) of both models was also prepared and provided to the Deputy Chief of Staff for Intelligence. This was

---

[1]RAND-ABEL is a trademark of RAND.

necessary because the Army's current V&V procedures are not fully appropriate to these models. At the time of this briefing, the Arroyo Center planned to conduct a follow-on study which would entail an assessment of the Army's IEW capabilities to support contingency operations in light of lessons learned from the Persian Gulf War and other recent operations. We anticipate that, if approved, the OPVIEW methodology and models can be applied to support this study.

ACKNOWLEDGMENTS

A number of individuals, both in the Army and at RAND, helped make this project successful. The key people, besides the OPVIEW team members, are mentioned here.

Mr. James D. Davis, the Deputy Assistant Chief of Staff for Intelligence (DCSINT) (Management) was the primary sponsor for this project. He, along with Lieutenant General Sidney T. Weinstein, the DCSINT at the time, correctly saw the need to be able to measure the value of intelligence at the operational level and contributed much insight about previous attempts that had proved unsuccessful.

MAJ Lester F. McConville was one of the first DCSINT Action Officers. He helped us obtain essential research materials during the early phase of the project.

COL Edward Gore performed admirably as the DCSINT Action Officer for the project during its most formative stage. He arranged important briefings and helped obtain essential data for the model's tables. He directly participated in one of the two special studies to apply the OPVIEW methodology in an actual case study.

LTC James Waite served as the DCSINT Action Officer during the last year of the project. He assisted greatly by arranging to review our Working Drafts and performing a number of important coordination tasks with members of the Army Staff.

MAJ Keith Marass performed as the DCSOPS Action Officer for this project.

Michael Powell, assigned to the Combat Developments Directorate at USAICS, Fort Huachuca, AZ, was involved in model development on the IEW Functional Area Model (FAM). He provided several substantive briefings on the status of the FAM model and helped critique the OPVIEW approach.

Woodson Tucker, assigned to the Combat Developments Directorate at USAICS, Fort Huachuca, AZ, was also involved in model development work on the IEW Functional Area Model. He also helped critique the OPVIEW approach.

Mr. William Clay, of AMSAA, Aberdeen, MD, contributed sensor performance data for some of the model's tables.

LTC Lance Tomei, an Air Force officer serving in an Army billet, was the first person outside of RAND to use the fledgling model (specifically, to analyze unmanned aerial vehicles [UAVs]). He provided helpful insights from a very knowledgeable intelligence officer's user perspective.

LTC Michael J. Diver, a RAND Army Fellow, served as the first Army intelligence officer assigned by the DCSINT to work with the OPVIEW team. He made important contributions to the development of the sensor and intelligence submodels, and guided much of the team's work by being the resident Army subject matter expert.

LTC William Knarr, also a RAND Army Fellow, served as the second and last intelligence officer assigned to the project. He developed the Southwest Asia scenario in its entirety and helped to integrate it into the model. This scenario was used in the second game trial. He also gave the team valuable insights from a subject matter expert's viewpoint concerning military operations in general, and more specifically, from an intelligence operator's perspective on IEW/TA systems and employment doctrine. His views were enormously valuable for guiding the team's efforts at crucial phases during both the methodology's and prototype model's development work.

As the first Director of the Arroyo Center, Steve Drezner realized the importance of the Army's being able to measure the value of intelligence and agreed to undertake the study, notwithstanding that at the time the project was approved by the Arroyo Center Policy Committee (ACPC) it was considered to be a high-risk endeavor. He was a key supporter and frequent mentor of the methodological approach during the project's formative stages. One key guiding factor was to carefully develop the methodology, giving greater attention to it in the beginning than to the model development work.

Marlin Kroger, a RAND consultant, gave unstintingly of his ideas and helped shape the project's direction during its early phase. Unfortunately, as a result of his untimely death, he was unable to continue with the project to its end; however, he made valuable contributions to the conceptual aspects of the methodology and his imprint on the project endured to its end.

Jefferson Marquis, a research assistant during the early stages of the project, helped organize and analyze categories for the measures of performance and measures of effectiveness of IEW/TA systems.

Steven Bankes was one of the principal intellectual contributors to a number of important philosophical issues related to simulation and model development. He suggested a rationale for and ways to employ aggregated data and perform sensitivity analysis and gave substance to exploratory modeling and variable resolutions approaches, which are major features of this Note.

Clairice Veit, who participated with Monti Callero in conceptualizing, designing, and applying the subjective transfer function method at RAND, helped develop representations of scenario-derived operational and intelligence requirements. She employed experimental designs obtained from military experts and conducted validity tests of them.

John Bondanella participated in scenario developments and helped formulate measures for the operational components and simulated events from the several conflict scenarios we used. He helped define terms that reflect operational realism in ways that could be best understood and used by the model's developers.

Together, Ed Hall, Loretta Verma, Robert Weissler, and Barry Wilson, respectively, designed the dynamic simulation model's intelligence, sensor, decision, and conflict adjudication submodels and integrated them into a single functioning prototype.

Philip Propper helped write several combat scenarios for the Arroyo Center's study in support of the Army's MI Relook study. He also did much of the work of entering and manipulating data for the value-added scoring process for the eleven scenarios developed for this phase of the work.

Together, Calvin Shipbaugh and Daniel Gonzales researched Army, Air Force, and Navy IEW/TA system descriptions and their characteristics.

John Clark gave OPVIEW briefings and served as the alternate Project Leader for a period of six months.

Together, William Schwabe and Richard Hillestadt performed a highly beneficial critique of the OPVIEW methodology and dynamic model at an important time in their development.

William Schwabe and Leland Joe provided insightful and comprehensive reviews of this Note.

We would also like to applaud Dee Lemke for her valuable assistance in designing and preparing the numerous tables and figures and for typing the many drafts of this Note. Regina Simpson, the Arroyo Center's Publication Assistant, assisted in preparing the final manuscript.

GLOSSARY

ACPC	Arroyo Center Policy Committee
AMSAA	Army Materiel Systems Analysis Activity
ASARS	Airborne Synthetic Aperture Radar System
BDA	Battle damage assessment
CPF	Collection probability factor
CCPF	Conditional collection probability factor
DA	Department of the Army
FAM	Functional Area Model
GRCS	GUARDRAIL common sensor
IEW/TA	Intelligence, electronic warfare, and target acquisition
IMINT	Imagery Intelligence
JSTARS	Joint surveillance and tactical acquisition radar system
MI	Military Intelligence
OPVIEW	Measuring the operational value of intelligence, electronic warfare, and target acquisition
PEO-IEW	Project engineering offices for intelligence and electronic warfare
PPBES	Planning, Programming, Budgeting, and Execution System
SIGINT	Signals intelligence
STF	Subjective transfer function
UAV	Unmanned aerial vehicles
VV&A	Verification, validation, and accreditation

Measuring the Operational Value of IEW/TA

Sponsor
Deputy Chief of Staff for Intelligence, HQDA

Co-Sponsors
Deputy Chief of Staff for Operations, Force Development, HQDA
Commander, US Army Intelligence Center

Figure 1 —Title Slide and Sponsorship

This Note documents the final, executive-level briefing for the project, "Measuring the Operational Value of Intelligence, Electronic Warfare, and Target Acquisition," commonly called "OPVIEW."

The OPVIEW project was initiated in 1988 to attempt to quantify the contribution of military intelligence assets and activities to the success of military operations.

The OPVIEW project sponsor is the Deputy Chief of Staff for Intelligence, Headquarters, Department of the Army. There were also two project co-sponsors: the Deputy Chief of Staff for Operations, Force Development, Headquarters, Department of the Army, and the Commander, United States Army Intelligence Center.

- Broad intelligence capabilities required to support contingency operations
- Force structure issues: types and quantities of intelligence collection, production, and dissemination systems to retain, eliminate, develop, modify, or procure
- Desired technical and operational characteristics of systems and system packages
- System employment doctrine and integration issues

Figure 2—Intelligence Policy Issues

Military intelligence policymakers are faced with a rapidly changing domestic and international environment. The likelihood of a large-scale high-intensity war against a familiar enemy has been significantly reduced. Instead, the likelihood of a smaller-scale conflict against an unfamiliar enemy has increased. As a result, the Army must be prepared to support operations in a wide variety of contingency operations in various regions and under different types of conflict states.

While the United States military force structure is decreasing, the need for highly capable intelligence support for operations is increasing. The varying conditions in the potential theaters of operations require a robust set of intelligence collection, processing, and dissemination assets. Similarly, potential enemies have varying threat capabilities, which adds to the requirement for support from a robust set of intelligence assets.

Not only must the technological requirements be met, but also the operational requirements, including the effects of employment doctrine and force integration issues. As a result, one must examine the contribution of packages of systems, and not look at the capabilities of only one system at a time.

- **Develop methodology for quantifying and measuring IEW/TA contributions to combat and noncombat operations across a wide spectrum of operations**
- **Develop analytic tools to support value assessments using the methodology**
- **Test the methodology by applying the prototype models to support current Army policy decisions**
  - **Eichelberger study**
  - **MI Relook Study**

Figure 3—Project Objectives

The objective of the OPVIEW project was to develop a methodology for quantifying and measuring IEW/TA contributions across a wide spectrum of operations. Although the initial project description only required examining intelligence support of combat operations, the objectives of the project evolved to encompass the increased emphasis on noncombat operations.

The approach used to accomplish these objectives was to develop an overarching methodology that could be applied by various tools. Two such tools developed were a static (i.e., time-independent) model and a dynamic (time-dependent) model.

As these research products were developed, they were applied to support ongoing Army research. The methodology was developed and refined during a June 1989 study, assessing the employment of selected Army Pacing IEW systems in Central Europe, requested by Major General C. B. Eichelberger the DCSINT. The static model was tested in the MI Relook Study headed by BG(P) John F. Stewart for MG Paul E. Menoher, Commander, U.S. Army Intelligence Center, Fort Huachuca, AZ.

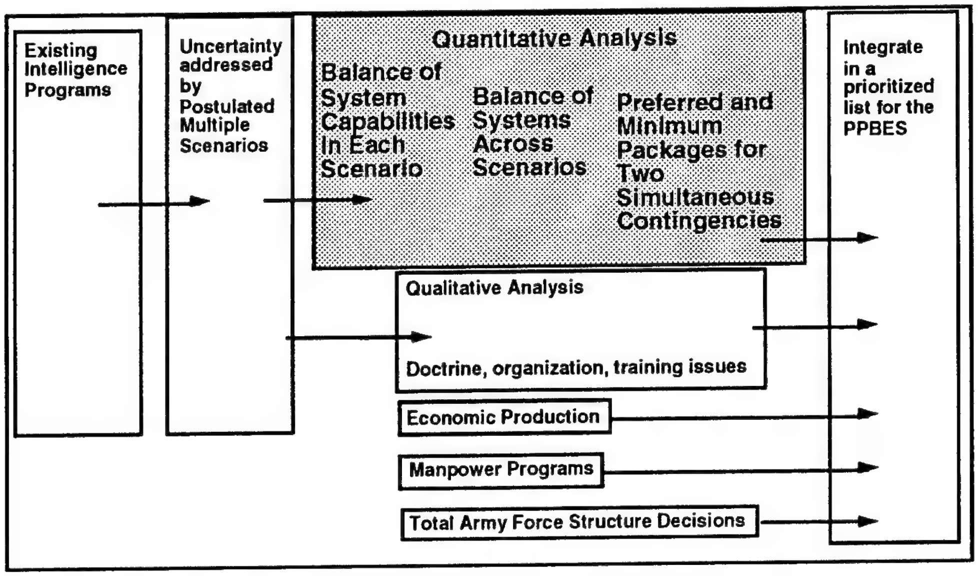

Figure 4—OPVIEW Support of Army PPBES

The OPVIEW methodology and models were developed to support the Army's PPBES process. The goal of the PPBES is to prepare a prioritized list of assets for Army acquisition. The OPVIEW methodology and models were developed to provide quantitative analysis of candidate intelligence systems as part of selected packages examined over a wide range of regions and conflict states. The result of the quantitative analysis is to provide the requirements for each type of asset for two concurrent contingencies. This information could be used to prepare prioritized lists for the PPBES.

However, additional factors must be considered when preparing such lists. These include qualitative factors, such as the effect of the candidate systems on doctrine, organization, and training. System costs, manpower requirements, and total Army force structure decisions must also be considered. The OPVIEW project has focused mainly on the quantitative analysis regarding system capabilities (shaded area).

When RAND was supporting the Army intelligence studies mentioned in discussion of the preceding chart, many of these factors were considered in secondary analysis. This briefing will describe only the OPVIEW quantitative analysis.

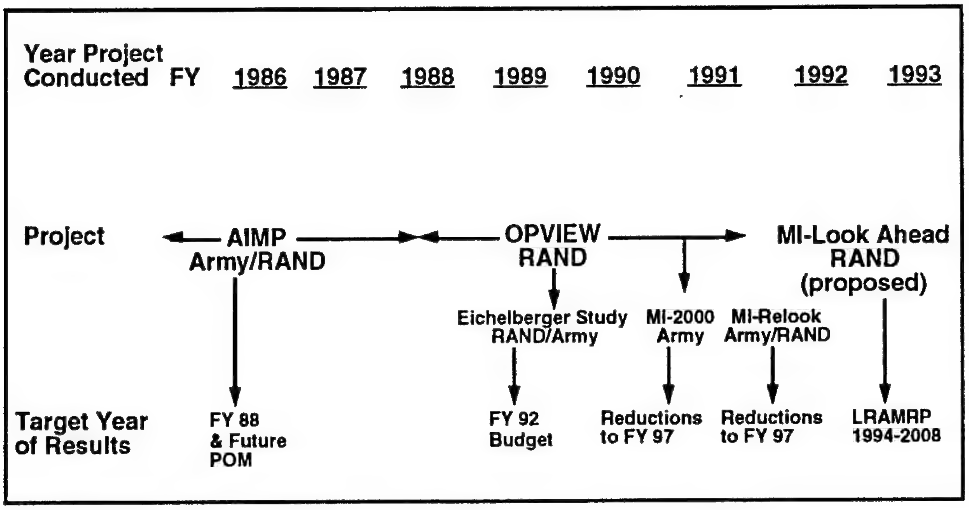

Figure 5—OPVIEW Project History

RAND participated in the development of the Army Intelligence Master Plan through fiscal year 1988. At that time, it was determined that the Army required a methodology to quantify the operational value of intelligence, electronic warfare, and target acquisition in support of the Army acquisition process.

Through fiscal years 1989, 1990, and 1991, the OPVIEW methodology was developed for and used in support of Army intelligence studies: the Eichelberger Study and the Army MI 2000 Relook Study.

Another study has been proposed by RAND to look at Army intelligence acquisition issues through the year 2008. It is anticipated that, if funded, the OPVIEW methodology and models will be used to support this study.

- Methodology
- Static model
- Dynamic model
- Project status and future directions

Figure 6—Outline

The first part of this briefing will focus on the OPVIEW methodology. The second part presents the design and illustrative results of the static model. The third part presents the design and illustrations of the dynamic model. The last part describes potential applications for the project's products.

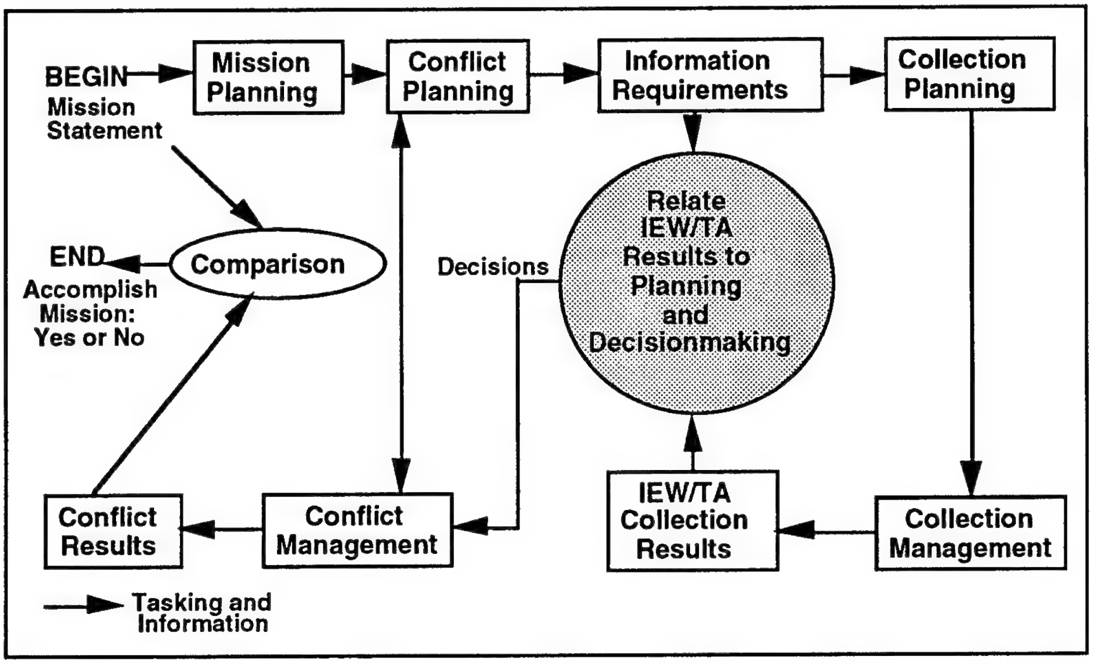

Figure 7—Overview of the Methodological Framework

The complete OPVIEW analytic process begins with the mission and ends with measures of the accomplishment of the mission. Between the starting and ending points are a number of processes that address mission planning, the commander's information needs, the intelligence collection to meet those information requirements, the perception of the conflict area presented to the commander, the effect of that information on the execution of the plan, and the operational outcomes.

Although this is a complex process, there is one particularly critical juncture, shown in the circle above. This juncture is the relation between the IEW/TA results and the commander's planning and decisionmaking. Without this connection, all of the other interactions may be well represented in a model, but the key effect of measuring the impact of intelligence on military operations would be lost.

The OPVIEW methodology focuses on this interaction—the circle in the diagram (shaded) above.

- **Employs top-down perspective and highly aggregated data**
- **Begins with a mission statement and ends with assessment of mission accomplishment**
- **Represents results of various processes (e.g., collection planning, collection management), but does not explicitly model the processes themselves**

Figure 8—Methodology Approach

To be applicable to a wide variety of scenarios the methodology was designed around a top-down approach. In this approach, intelligence asset capabilities are measured with respect to their purpose, i.e., their ability to support the commander's plan. (By contrast, a bottom-up approach would focus on collection system characteristics and attempt to fuse this information into a coherent picture.)

In the OPVIEW approach, the plan is defined to accomplish the mission, the information requirements are defined to support the plan, and the intelligence assets are measured with respect to their ability to provide this information in a timely manner. In addition, the intelligence assets are measured with respect to their contribution to provide this information as part of an intelligence package, rather than as individual collection assets.

Because of this top-down approach, the OPVIEW methodology and models do not explicitly represent system level activities such as the characteristics of signals or the number of threat emissions over time. Only the effects of activities by intelligence assets to provide the required information are presented.

- **Employs measurement criteria that integrate IEW/TA-system level performance with commander's information needs**
  - **Employs collection probability factors (CPFs), plus reporting times, for each IEW/TA system**
  - **Modifies system performance by environmental conditions and operational constraints to produce conditional collection probability factors (CCPFs)**
- **Relates information and intelligence results to decisionmaking, conflict planning, and execution**
- **Uses subjective transfer function for generating judgmental aspects**

Figure 9—Methodology Approach (continued)

The primary measure is called the collection probability factor, or CPF. The CPF is the best a system can do to provide the required information, not accounting for degradations caused by conditions such as terrain, weather, and enemy active and passive countermeasures. CPFs are defined to be between zero and one, where one represents perfect capability to provide the required information. After accounting for the effects of these degradation factors, the resulting measure is known as a CCPF, or conditional collection probability factor. CCPFs are also defined to be between zero and one.

Since the OPVIEW models accept as inputs data that represent subjective expert judgments, we devised a disciplined, systematic, and rigorous approach to define and manage subjectivity. The intent was to limit and expose uncertainty as much as possible and to distinguish between those areas where general agreement exists, based on proof, and where consensus might be problematic.

We distinguish two levels of subjectivity in system performance measures. CPFs, the less subjective measure, represent expert judgments of a system's performance under ideal circumstances given its design characteristics and physical laws. CCPFs, the more subjective measure, represent complex expert judgments that are based not only on the data that comprise CPFs, but also on data regarding expected environmental and operational conditions and the system's expected (usually degraded) performance under those conditions.

In our experience, military operations and intelligence experts are able to reach consensus readily in their judgments of system performance at both levels when given sufficient credible information. Moreover, when it is not available, they are better able to request the information they require to make their judgments. The quality (validity and reliability) of these expert judgments can and should be tested to improve the data.

Since judgment has been used extensively to create both the CPFs and the degradation factors necessary to obtain the CCPFs, we needed a way to assure that these judgments were reasonable (and to test that reasonableness). The project investigated the subjective transfer function (STF) approach as a way to do so, although actually applying the methodology in this way would require a significant new effort—i.e., this project described an approach to verification, validation, and accreditation (VV&A), but did not try to implement it. The next two slides describe features of the STF approach.

Once CPF and CCPFs are established for each intelligence asset, one can measure the capability of a package (i.e., a mix of specific types and quantities) of assets to provide the required information under different degradations caused by environmental effects and enemy activity.

- Provide a common value measuring system across all collection means
- Relate intelligence collection capabilities to commander's information requirements
- Develop and compare alternative collection packages across various regions, conflict states, and missions

Figure 10—Purpose of the Methodology

The purpose of the methodology is to provide a "common value" system for measuring all information requirements and the capabilities of all intelligence systems. This common value must be useful from an operational perspective in terms of the information required to support the plan, and in terms of the information that can be provided by intelligence means to satisfy the plan's requirements.

The methodology must be sufficiently robust to allow different combinations of collection means to be compared under the variety of conditions that may be encountered around the world, in different regions, and under different conflict states.

- Use for complex system analyses
- Factors defining a complex system (e.g., military intelligence) are:
  - selected with the help of system experts
  - hierarchically structured
- Factors are manipulated in judgment experiments
  - manipulated factors form scenarios to which experts respond
  - experts' responses are used to test judgment theories that describe how factors affect judged system outcomes
  - the selected STF is the judgment theory that accounts for the experts' judgments
- STFs serve to measure effects of factors on outcomes within or external to the system

Figure 11—Features of the STF Approach

The STF is an approach to estimating effects of complex system factors on system outcomes using human judgments. Factors defining a system are selected with the help of system experts and are hierarchically structured to represent the system under investigation. The approach incorporates the testability features of "algebraic modeling," developed in the area of psychology. Factors are manipulated in experimental designs that allow tests among judgment theories (in the form of algebraic models) to explain experts' judgments. Typically, different groups of experts know about different aspects of a system. The theory that passes its explanatory tests for a particular expert group is the STF or underlying judgment theory for that group. The STF for each expert group estimates the effects of system capabilities on judged outcomes. The set of STFs across expert groups functionally interlink to produce an overall system effectiveness measure. The interlinking function feature eliminates some of the problems of using assumed but untested rules for aggregating across hierarchical tiers found with other approaches. The resulting estimates may or may not be correct in predicting real-world outcomes, but they are "serious" estimates, systematically developed.

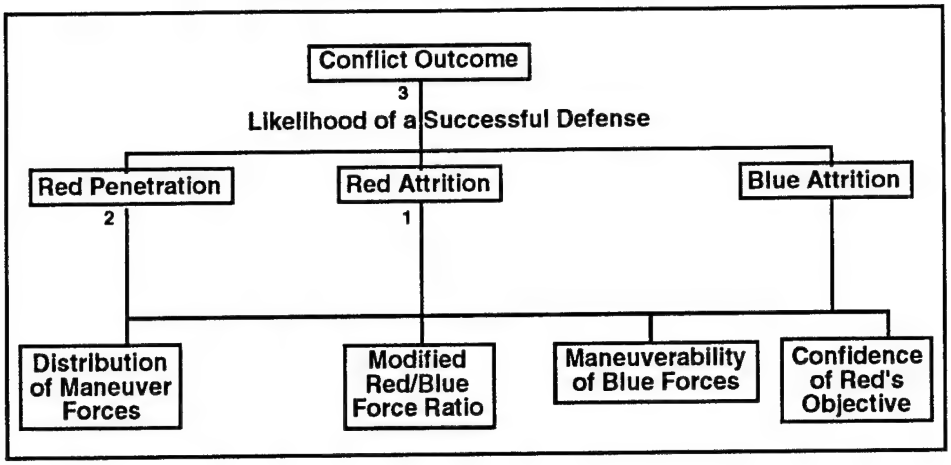

Figure 12—Abbreviated STF Intelligence Structure

This chart depicts a three-tiered abbreviated version of an STF intelligence structure. At the top of the structure is the judged conflict outcome—the likelihood that friendly forces will successfully defend their area, that is, contain the attack and maintain their viability as a combat force. The entire structure consists of an intelligence section of hierarchical tiers below the operational outcomes portion of the structure depicted here.

Operations officers from Ft. Leavenworth and intelligence officers from Ft. Huachuca helped develop and define the factors; the operations officers from Ft. Leavenworth served as respondents in the three experiments outlined above: estimating the degree of (1) Red attrition and (2) Red penetration that could result under different levels of the four factors constituting the lowest hierarchical tier; and estimating (3) the likelihood that Blue's defense would have been successful under different outcomes described by the three factors at the middle hierarchical tier. (Note that the four factors at the lowest hierarchical tier are also depicted to affect Blue attrition. These judgment data were not collected in this study.)

Commander's Information Needs

(Coverage and Timeliness Requirements)

- Detect
- Locate Generally
- Locate Precisely
- Classify
- Identify
- Track
- Acquire
- Assess Operational Capability

Figure 13—Requirements for Commander's Information Needs

To create a common measure, we examined over 300 prioritized intelligence requirements (PIRs) and other information requirements (IRs) to determine if there were any commonalities among them. We found 8 common requirement factors that could be used to define all of the PIRs and IRs we analyzed. Each of these factors can be assigned quantitative coverage and timeliness requirements.

For example, sometimes a commander wants to know whether or not the enemy is present in a given area. Therefore, he needs only to detect the presence of enemy forces to satisfy that information requirement. Similarly, he may want to know the general or specific location of enemy forces. As an alternative, he may need to classify enemy units to determine the location of the armor division in a corps. Or he may want to identify the unit to determine the location of the 3rd Guard's Regiment. He may need to track a unit to determine its direction of travel and estimated arrival time. Or he may need to acquire targets in a target area of interest. Finally, he may need to perform battle damage assessment (BDA) to support restrike and assess a unit's operational capability after damage assessment.

In most cases, the timeliness requirement tends to increase with the categories of track and acquire, which require real time or near real time reports. BDA in support of restrike may require near real time feedback, and situation development may be supported by longer time horizons.

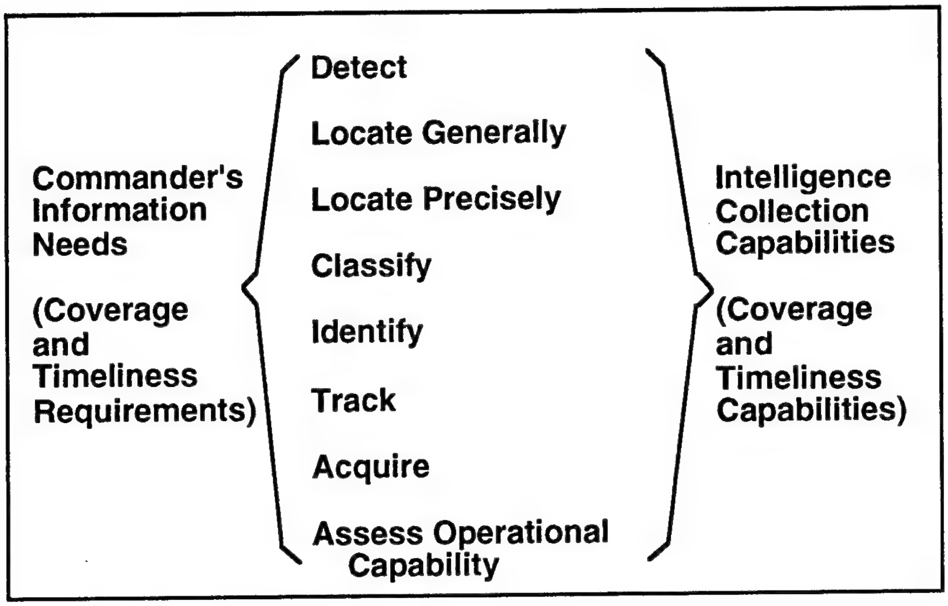

Figure 14—Coverage and Timeliness Capabilities by Collection Asset

The ability of the intelligence collection assets to provide the required information is measured on the same scale. Each asset (as part of a package of assets) will provide a certain degree of coverage within a specified amount of time.

Coverage is defined as a geographic area being "observed" by one or more sensors with sufficient resolution to provide a degree of confidence that what is present can be detected, or located generally, or located precisely, etc. For example, a CCPF of 0.5 for "identify" means that one is only 50 percent sure that the observed unit is identified. The higher the CCPF in each category, the more certain one is of that information.

Once this process has been applied, the key requirement of relating the intelligence collection capabilities of various systems to the commander's information needs is satisfied.

- **RAND analysis**
- **Army Materiel Systems Analysis Activity (AMSAA)**
- **RAND Army Fellows – intelligence officers assigned to the OPVIEW project**
- **Department of the Army (DA) staff members**
- **Other Army experts**
  - **Fort Huachuca U.S. Army Intelligence Center (USAIC)**
  - **Fort Leavenworth Project Engineering Officer for Intelligence and Electronic Warfare (PEO-IEW)**

Figure 15—Sources of Data for CPFs and CCPFs

Since all of the CPFs and the degradation factors for the CCPFs are subjective, the project devoted considerable time in determining values to use for these parameters. In addition to the work performed at RAND, we collaborated with Army Materiel Systems Analysis Activity (AMSAA) regarding the CPFs. In addition, Army Fellows with intelligence backgrounds stationed at RAND were asked to define parameters and to help prepare the scenarios.

Members of the Department of the Army staff, intelligence experts at Fort Huachuca, and operational experts at Fort Leavenworth also contributed, as well as members of the U.S. Army Intelligence Center and the project engineering officer for intelligence and electronic warfare (PEO-IEW).

The numbers employed most definitely need further refinement. However, one main feature of OPVIEW is that these parameters and their assumptions are open and available for review, and can be readily changed in the models. Follow-up work should include much more extensive use of physical data and experimentation, and more detailed analysis, but even the first-cut values used for calibrating the prototype model were the result of considerable work.

Since the outputs of the OPVIEW methodology and models depend critically on the quality of the inputs, care should be taken in developing these subjective judgments.

- Methodology
- Static model
- Dynamic model
- Project status and future directions

Figure 16—Outline

This part of the briefing will discuss the application of the methodology to the static model.

- Assess capability of alternative collection systems and system packages to meet commander's information needs
- Developed to permit application of the OPVIEW methodology to support the MI Relook Study
  - Fast running to permit the quick analysis of many cases across regions, conflict states, and missions
- Easy to understand, facilitating interaction among various users (research analysts, intelligence experts, resource allocators, and operational planners)
  - Implemented on Microsoft Excel spreadsheet on Macintosh
- Can be used in screening tool for more detailed analyses with the dynamic model

Figure 17—Purpose of the Static Model

The static model assesses the capability of alternative collection systems as part of system packages to meet commanders' information needs. The model is called "static" because it does not represent time and the sequencing effects of time, except for the broad phases of an operation (such as indications and warning, campaign planning and execution, and reconstitution). In contrast, the dynamic model represents the sequence of events over time—i.e., through the course of the operation as it evolves—and with less aggregation of effects. The static model can also be used as a screening tool for the dynamic model so that only the most important cases or those requiring more detailed analysis of specific aspects of a simulation—e.g., area coverage over time, timeliness of information to support a plan, system interoperability—need be run in the dynamic model.

The static model was developed to support the MI 2000 Relook Study. As a result, the model had to be fast running to permit rapid analysis across many regions, conflict states, and missions. (The model was implemented on Microsoft Excel spreadsheets on a Macintosh computer.)

Since many organizations were involved in the study, the model had to be easy to understand to facilitate the interaction between the various users (research analysts, intelligence experts, resource allocators, and operational planners).

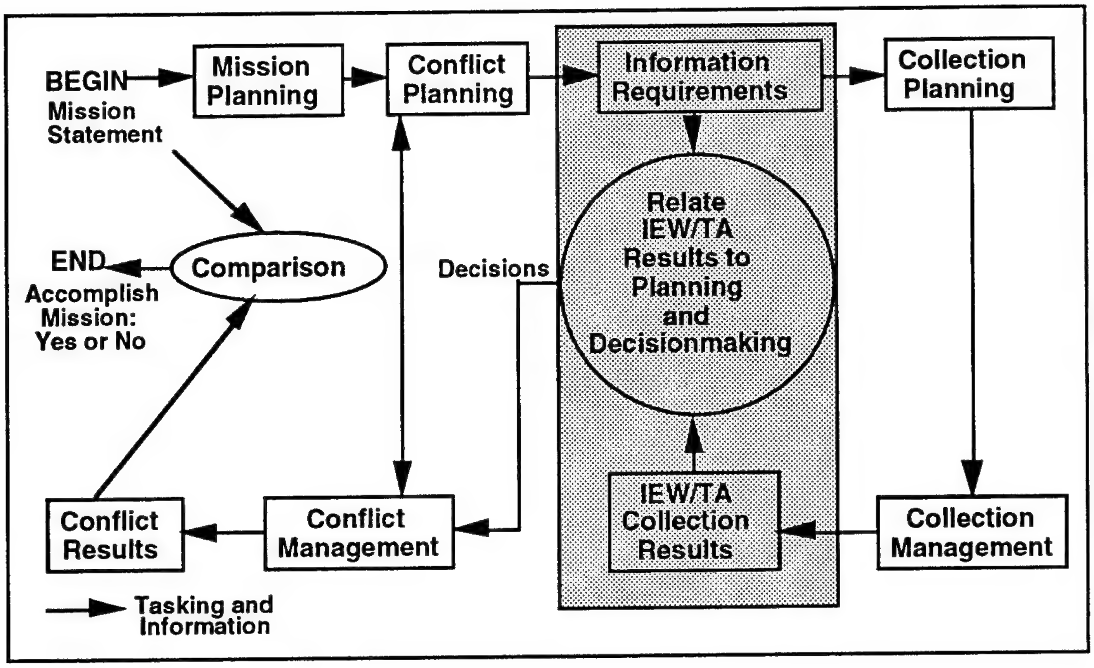

Figure 18—Scope of the Static Model

The scope of the static model is limited to the commander's information requirements and the ability of the intelligence assets to meet those requirements under a variety of environmental conditions and enemy activities. There is no "sequence of events" in the static model, but rather an aggregate snapshot of the conditions under which the sensors would have to perform.

For example, if the likely enemy avenues of approach are 20 percent in open, 30 percent in mixed, and 50 percent in closed terrain, then the composite effect of these types of terrain is produced by a weighted average. Similarly, if the weather is clear 20 percent, cloudy 60 percent, and stormy 20 percent of the year, then these effects are combined in a weighted average as well. If one wished to focus only on certain times of the year or only on selected avenues of approach, this analysis may be performed as well.

To obtain the weightings, we estimated the portion of the terrain that had limited, open, and mixed line of sight. Mountainous, forested or jungle, and urban terrain were all considered to be closed—that is, have a limited line of sight to a potential target. Flat terrain with sparse vegetation was considered to be open terrain, with good line of sight to a potential target. A combination in-between was considered to be mixed terrain. The types of terrain in the areas of interest were

estimated as the fraction in each of these three categories and were normalized to sum to the number one.

In addition to terrain, the weather that would occur in the region was estimated over the course of a year. Weather was divided into three categories: clear, cloudy or rainy, and hazy (during which the sky is assumed to be not as opaque to some sensors as with full cloud cover, but not clear). Based on broad, annual estimates of rainfall and cloud cover in each region, estimates were made of the fraction of time the weather fell into one of the three preceding categories. The weather fractions were also summed to the number one.

Overall, there is no representation of the interaction between the information collected and the decision process, since the static model is time-independent. It cannot be used to analyze the effects of intelligence or the commander's decisions through the course of an operation. The decision module in the dynamic model was developed for that type of analysis.

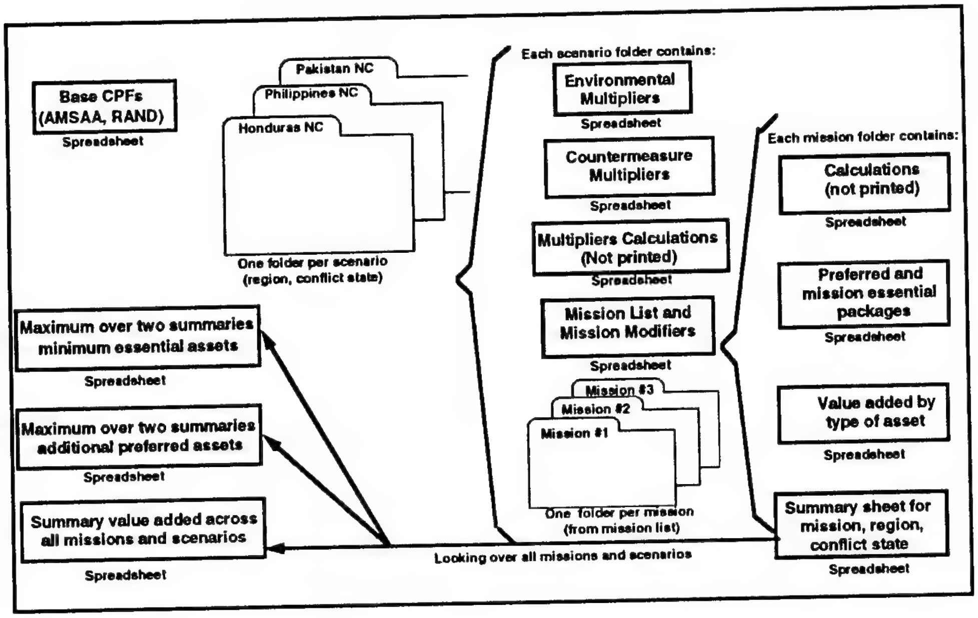

Figure 19—Architecture of the Static Model (Excel spreadsheets on a Mac)

The static model is arranged in the following manner on Microsoft Excel spreadsheets on a Macintosh computer. Starting at the upper left, the basic CPFs are stored for each collection asset under ideal conditions. There are 11 folders, one for each scenario, which is a combination of region and conflict state. Within each scenario folder are spreadsheets that contain the parameters and calculations for the environmental and countermeasures degradation effects. There are also discount factors for the 8 intelligence tasks (detect, locate generally, etc.) as a function of the missions being performed in that scenario. Each scenario folder currently contains between one and four missions.

Each mission folder contains the definition of the minimum essential package to perform operations in this region and conflict state. The folder also contains the definition of the preferred package to better support operations in that scenario. If there are any synergistic considerations, such as joint surveillance and tactical acquisition radar system (JSTARS) cueing unmanned aerial vehicles (UAVs) for targeting purposes, these interactions must be accounted for in the definition of the minimum essential package. To retain its simplicity the static tool is not designed to model such synergistic interactions explicitly. The mission folder also contains discount factors for timeliness (if slower assets are being used to fulfill real or near

real time requirements based on the timeliness criteria), and for availability (i.e., if not an Army system, it may not be sufficiently responsive when needed).

The results are aggregated and combined for each scenario, and the maximum requirements for each type of asset over two scenarios are obtained.

IEW/TA Systems	Detect	Locate Generally	Locate Precisely	Classify	ID	Track	Acquire	BDA
Type 1	0.95	0.95	0.90	0.85	0.0	0.95	0.85	0.0
Type 2	0.95	0.90	0.85	0.25	0.3	0.15	0.30	0.0
Type 3	0.95	0.80	0.75	0.90	0.3	0.7	0.9	0.8
Type 4	0.95	0.95	0.90	0.80	0.0	0.9	0.75	0.0
Type 5	0.95	0.90	0.80	0.85	0.5	0.3	0.75	0.0
Type 6	0.95	0.95	0.95	0.90	0.4	0.9	0.8	0.9

Figure 20—IEW/TA System Base Collection Probability Factors (CPFs)

The base CPFs define the best that each type of asset can do to provide information for each of the 8 functions. For example, JSTARS can do very well at tracking enemy forces, but is useless for identifying enemy forces or performing battle damage assessment (BDA) (see type 1 above). Similarly, a signals intelligence (SIGINT) asset may do well for identifying enemy units, but would not perform either tracking or BDA well (see type 2 above). Finally, imagery intelligence (IMINT) and human intelligence (HUMINT) may do very well across the board, but be more susceptible to terrain, weather, and enemy countermeasures (see type 3 above).

The numbers listed above are merely examples; they serve to illustrate the procedure for calculations in the static model. The numbers are simply the best estimates obtained from subject matter experts and should not be considered as sacrosanct. However, they can serve as useful "placeholders" until better estimates can be developed to replace them by employing either the STF or any other credible approach.

MISSION MODIFIERS (column multipliers) Mission: Peacekeeping								
Systems Type	Detect	Locate Generally	Locate Precisely	Classify	ID	Track	Acquire	BDA
Phase 1 (I&W)	1.00	1.00	0.30	0.50	0.3	0.50	0.0	0.0
Phase 2 (Crisis Mgmt)	1.00	1.00	0.30	0.50	0.3	0.50	0.3	0.2
Phase 3 (Combt Exec.)	0.70	0.80	0.90	0.90	0.7	0.8	0.9	0.7
Type 1 (JSTARS)	0.95	0.95	0.27	0.43	0.0	0.48	0.0	0.0
Type 2 (GRCS)	0.95	0.90	0.26	0.13	0.1	0.08	0.0	0.0
Type 3 (ASARS)	0.95	0.80	0.23	0.45	0.1	0.35	0.0	0.0

Figure 21—Mission Modifiers for Conditional CPFs (CCPFs)

The mission modifiers are used to de-emphasize those of the 8 intelligence functions not required by a given mission. For example, during a peacekeeping mission (mission 1 above), there is no need to acquire targets or perform BDA. Conversely, a combat mission (mission 3 above) will place strong emphasis on tracking, acquiring, and performing BDA on targets.

The mission modifiers act as column multipliers for the CPF matrix. In the numerical example the mission modifiers for mission 1 (peacekeeping) were used in the matrix below it. As a result, there is no requirement to acquire targets or perform BDA for any of the assets performing this mission.

The logic used for summing the rows, rather than combining their numbers another way, was arbitrary and could be easily changed. For example, if the line-of-sight between a single direct-viewing sensor and an intelligence target was obstructed "n" percent of the time because of terrain, any additional obscuration attributable to moisture in the atmosphere because of weather would apply only when the terrain did not interfere. Adding the weather effects on top of the obscuration by terrain at other times would be moot.

Where more than one sensor of the same type is employed in the same area and time, some of the sensors would be affected by the terrain (or countermeasures) part of the time and also by the weather at other times. More work is recommended

to determine the best ways to combine the numbers. Undoubtedly, some will be both regional and sensor dependent and it may be possible to resolve this with analysis using the dynamic model.

Mission: Peacekeeping

MISSION MODIFIERS
(column multipliers)

TYPE OF SENSOR
CPF MODIFIERS
(row multipliers
for each type)

Terrain
Weather
Countermeasures
Active
Passive
Timeliness
Availablity

Phase 3 (Cmb. Exec.)	1.00	1.00	0.30	0.50	-----
System Type	Detect	Locate Generally	Locate Precisely	Classify	-----
Type 1 (JSTARS)	0.80	0.80	0.23	0.36	-----
Type 2 (GRCS)	0.78	0.74	0.21	0.11	-----
Type 3 (ASARS)	0.71	0.60	0.17	0.34	-----
-----	-----	-----	-----	-----	-----

Figure 22—Sensor Modifiers for Conditional CPFs (CCPFs)

The remaining modifiers are all row multipliers; that is, they affect all 8 functions equally. For example, the terrain, weather, countermeasures, timeliness, and availability multipliers are defined for each type of sensor and affect all 8 intelligence functions. Different types of sensors will be affected differently. For example, JSTARS will not be much affected by poor weather, while IMINT systems will be affected by poor visibility. Countermeasures include active and passive countermeasures. Active countermeasures account for the enemy's ability to destroy the sensor platform. The higher the platform survivability (such as a standoff sensor), the smaller the degradation factor. Put another way, the more survivable the platform, the longer it can provide the necessary coverage. Passive countermeasures include enemy actions to avoid detection. For example, a stationary unit will not be seen by moving target indicators. Units using camouflage will be harder to detect. Units using electromagnetic emissions control (EMCON) will reduce the ability of SIGINT assets to detect them. All degradations are considered to affect a given type of asset's ability to perform any of the 8 intelligence functions listed above. The spreadsheets have been designed to handle the case where any effects would degrade only one of the 8 intelligence functions for a specific type of sensor, although all of these multipliers are currently set to 1.0 (no effect).

Combat

- Honduras
- Israel-Syria
- North-South Korea
- Europe, Poland-Russia
- NBC Crisis Response
- Southwest Asia, Saudi Arabia

Noncombat

- Honduras
- Israel and Persian Gulf
- North-South Korea
- Philippines
- Pakistan-India

Figure 23—Operational Scenarios Analyzed to Date (MI 2000 Relook Study)

In support of the MI 2000 Relook Study, the static model was used to analyze the contributions of intelligence assets to meet commanders' information requirements in the scenarios listed here. There were nine different regions examined under combat and noncombat operations, for a total of 11 scenarios. There were six combat and five noncombat scenarios.

The noncombat scenarios included peacekeeping operations, noncombatant evacuation operations (NEO), and low-intensity conflict (LIC).

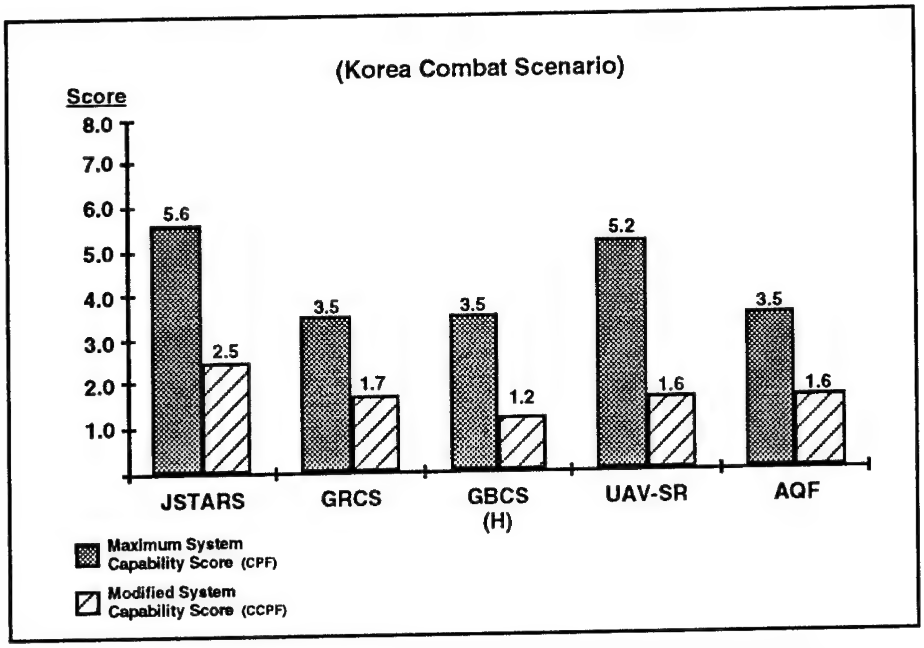

Figure 24—Operational Impacts on Collection Systems

This graph shows the estimated operational capability of each type of sensor to meet the commander's information needs in the Korean combat scenario. The dark bars represent the CPFs, or the maximum row-sum score for that type of asset under ideal conditions. The light bars represent the CCPFs, or the ability to meet the commander's information needs under operational degradations. (Since there are 8 intelligence functions, the maximum score any sensor could obtain is 8.0.)[2]

Note that the operational value (CCPF) of JSTARS is less than half of its ideal or CPF value. This is primarily due to the terrain line-of-sight problems encountered in the Korean theater of operations. However, also note that the UAV-SR is reduced by a factor of four. In addition to terrain effects, severe weather reduces the UAV's ability to see or even to fly. Also, the enemy active countermeasures can degrade the UAV-SR, while it cannot affect the JSTARS because of its standoff range.

If one were to simply rank the CPFs, the JSTARS and the UAV-SR have the two highest values. If, however, one looks at the ranking of the CCPFs, the JSTARS

---

[2]Although we examined many different combinations of normalized and non-normalized measures for the composite CCPFs, we concluded that a row-sum would be an adequate measure for the MI 2000 Relook Study. (One may choose to normalize these values in a different study and apply different weighting factors for more or less likely scenarios.)

and the GRCS are rated the highest. That is why it is important to examine the operational value of each asset as part of a given collection package.

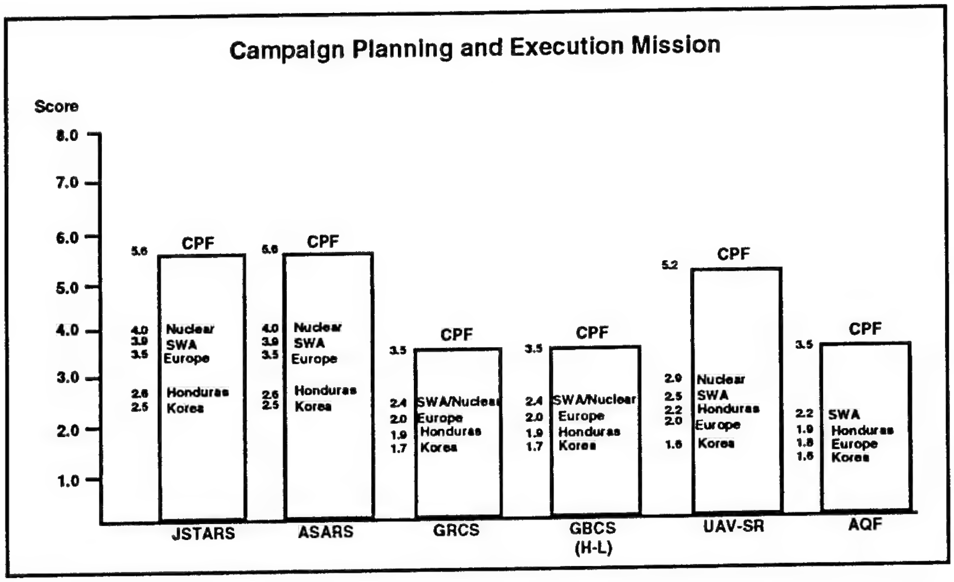

Figure 25—Results Across All Combat Scenarios

This graph compares CCPFs by asset type and region over all combat scenarios. The maximum (CPF) value is shown for each, as well as the operational values (CCPFs) for these 5 factors.

For example, the JSTARS, with CPF value 5.6, has a CCPF value of 4.0 in the nuclear scenario, 3.9 in the SWA scenario, 3.5 in the Europe scenario, 2.6 in the Honduras scenario, and 2.5 in the Korea scenario.

By contrast, the UAV-SR has a CPF of 5.2, a CCPF of 2.9 in the nuclear scenario, 2.5 in the SWA scenario, 2.2 in the Honduras scenario, 2.0 in the Europe scenario, and 1.6 in the Korea scenario. Note that the performance ratings of the assets vary by region.

	System Type	System Quantity	Added value of each system on preferred list across all scenarios		
			MIN	AVG	MAX
"A" List (Minimum Required)	1	62			
	2	39			
	3	8			
"B" List (Additional for Preferred Package)	1	22	.22	.29	.35
	2	22	.15	.32	.48
	3	4	.04	.04	.04

Figure 26—Desired Output to Support Army PPBES

Since the purpose of the static model is to provide input to the Army's PPBES process, the list of assets considered for purchase is divided into two. The "A" list includes the quantity of items for each type that appears on the minimum essential list. Including all minimum essential assets of a package on the list ensures that all of the necessary synergistic effects are accounted for and not ignored.

For example, if UAVs require JSTARS to cue them to a target, then both JSTARS and UAVs will appear in the minimum essential list. The maximum number of assets over two scenarios determines the quantity of assets by type that appear on the "A" list.

The "B" list includes the difference between the minimum essential quantity and the quantity of assets that would be preferred for performing operations over the maximum of two scenarios. Since the "B" list contains only those that would be desired if sufficient funds are available, one needs to know the marginal value of each additional asset that could be purchased.

This marginal value can be measured in many different ways. We examined three: the minimum marginal added value over the scenarios, as well as the average and the maximum. The spread of these three values can provide a quantitative input to the PPBES process. However, the marginal value or value-added is not the only criterion to consider. One must also consider the cost of each item, the personnel requirements, and the effect each asset will have on the Total Army force structure.

- Methodology
- Static model
- → Dynamic model
- Project status and future directions

Figure 27—Outline

This part of the briefing will discuss the dynamic model, explaining how it differs from the static model.

- **Simulates contributions of IEW/TA assets and activities to operational outcomes in specific scenarios**
  - **Wide range of regions, conflict states, missions**
- **Simulates the effects on collection due to terrain, weather, and countermeasures**
- **Models commander's decisionmaking, including selection of alternative courses of action**
  - **Two-sided**
- **Provides graphic displays of coverage results**

Figure 28—Purpose of the Dynamic Model

The purpose of the dynamic model is to simulate the contributions of IEW/TA assets and activities to operational outcomes through the course of a specific scenario. One could also define alternative scenarios or provide additional detail to the scenarios already examined by the static model.

One key difference between the dynamic model and the static model is that there is less aggregation in the dynamic model. Rather than use a composite value for the degradation caused by terrain and weather, as in the static model, the dynamic model examines the degradation of the CCPF of a sensor looking at an enemy unit on a specific type of terrain, day or night, during a specific type of weather, while the enemy is employing a specific set of countermeasures.

A second key difference is that the dynamic model represents the effect of information on the commander's decision process, and the feedback between that decision process and the allocation of forces and intelligence assets. The decision process in the model allows the simulated commander to select between alternative courses of action as a function of the information provided by the simulated sensors. The analyst establishes his own criteria so the model doesn't have to account for different types of commanders, e.g., aggressive, cautious, or prudent. In addition, the model is two-sided, with separate perceptions of the conflict area for each side.

There are also graphic displays of intelligence asset coverage over the area over time, as is shown below.

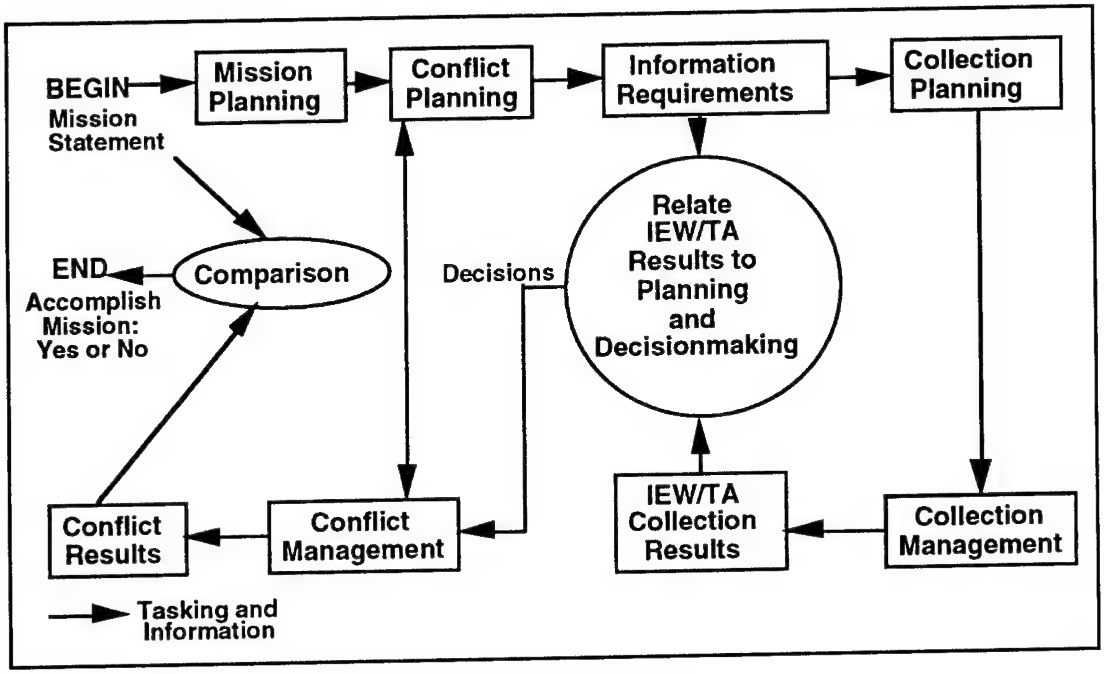

Figure 29—Scope of the OPVIEW Dynamic Model

The scope of the dynamic model includes all of the steps of the OPVIEW analytic process, from mission planning to mission accomplishment. Unlike the static model, the dynamic model represents all of these areas, at low to high resolution. The dynamic model is not as detailed in low-level resolution or line-of-sight weapon firing data as other Army models, such as JANUS, VIC, or IEW-FAM.

At the present time the dynamic model is a workable prototype. It has been demonstrated to connect, end-to-end, all of its submodels and provide results for analysis. Since it is table driven it represents a convenient place to enter, challenge, update, improve, store, and use the latest and most credible estimates from subject matter experts supported by actual physical measurements derived from systems. The model enables these data to be presented in a logical and coherent manner, according to the methodology developed, for performing analysis to support future studies.

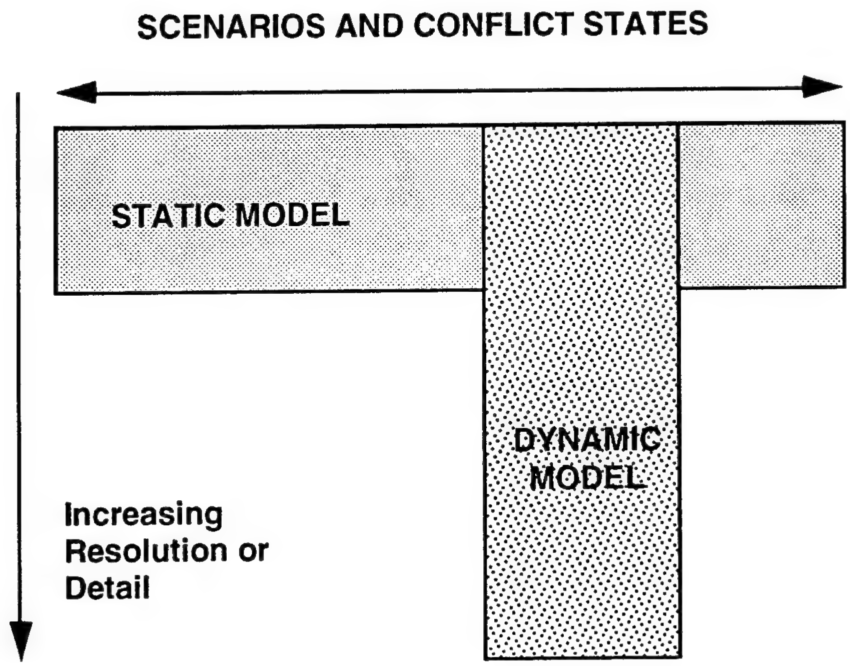

Figure 30—Using the Static and Dynamic Models Together

The differences between the static and dynamic models are shown above. The static model emphasizes breadth, covering a wide range of regions and conflict states, but with little detail. The dynamic model has much more detail than the static model, but examines only one region and conflict state at a time.

It is intended that the two models be used together when supporting a given study. The static model should be used first to determine which scenarios warrant detailed examination. Then the dynamic model can be set up to examine a specific scenario in more detail, focusing primarily on interactions not represented in the static model.

As the results from the dynamic model are obtained, the static model results can be updated to reflect this information.

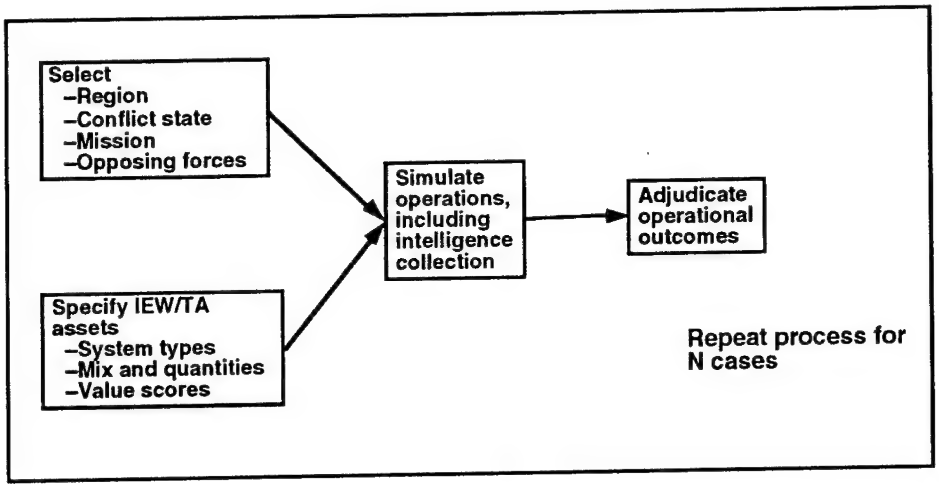

Figure 31—How the Dynamic Model Functions

The dynamic model is used in the following manner. First, one selects a region, conflict state, opposing forces, missions, and the objectives, plans, and PIRs for each side. Next, one selects the types of systems to be examined, their mix and quantities, and how they would be employed in support of the plan. In addition, one should examine the key degradation factors associated with the region to ensure that they apply.

The model is mainly deterministic, although it has some stochastic features. For example, weather or attrition to sensor platforms can be either deterministic or stochastic. In the deterministic mode, the probability of kill against a sensor system results in partial damage to it, so that its coverage is proportionally reduced. In the stochastic mode, the sensor platform either survives or is shot down as a result of the random (computer-generated) die-roll. The probability of being shot down is a function of the enemy threat to the sensor at that time and place. The analyst selects which modes and which tables he wants used as inputs to a model's run.

These and other data are fed into the model, which then simulates the operations, including the intelligence, decision, and assessment functions. The model is run to a conclusion and examined for the necessity to rerun cases. For example, if the sensor allocations did not adequately support the PIRs, the sensor allocation over time may have to be modified.

Once a correct run is completed, the process is repeated for N cases, where the user may vary the mix of sensors and plans and may even change theaters or regions

of operation. The greater the changes, the more the data must be modified before performing the next run.

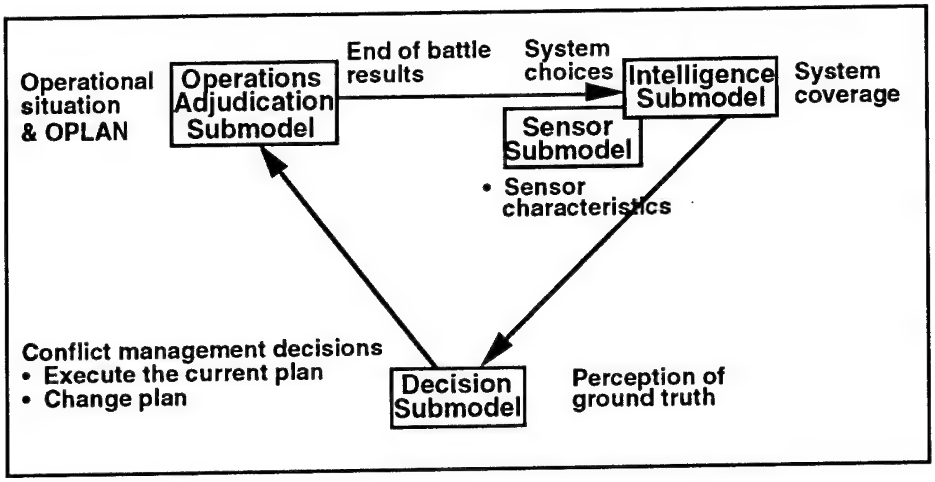

Figure 32—The Model's Architecture

There are three major submodels in the OPVIEW dynamic model. The most important one is the decision submodel. In this submodel, the plan for each side is specified. There are usually different phases to a plan, each with different PIRs. For example, a counterattack may include phases that specify when to leave the assembly area, when to reach the jump-off point, and when to launch the actual counterattack. If sufficient information is not available at the decision points, or if the perceived conflict situation does not meet the requirements for a successful counterattack, a change of plans may be required.

The decision submodel sends orders to the operations adjudication submodel to execute orders by forces. In addition, orders are sent to the intelligence platforms to collect information on the PIRs.

As information is returned from the sensors through the intelligence process, a perception data base for each side evolves over time. The decision model bases its decisions on the perception data base, including decisions to change plans or to continue with the existing plan.

The process continues through each submodel until the operation is completed (whether successfully or unsuccessfully). To help mitigate the effects of poor decision processes in the model, the intention is to always compare results with different mixes of assets in the same situation to determine which mix was better for that situation.

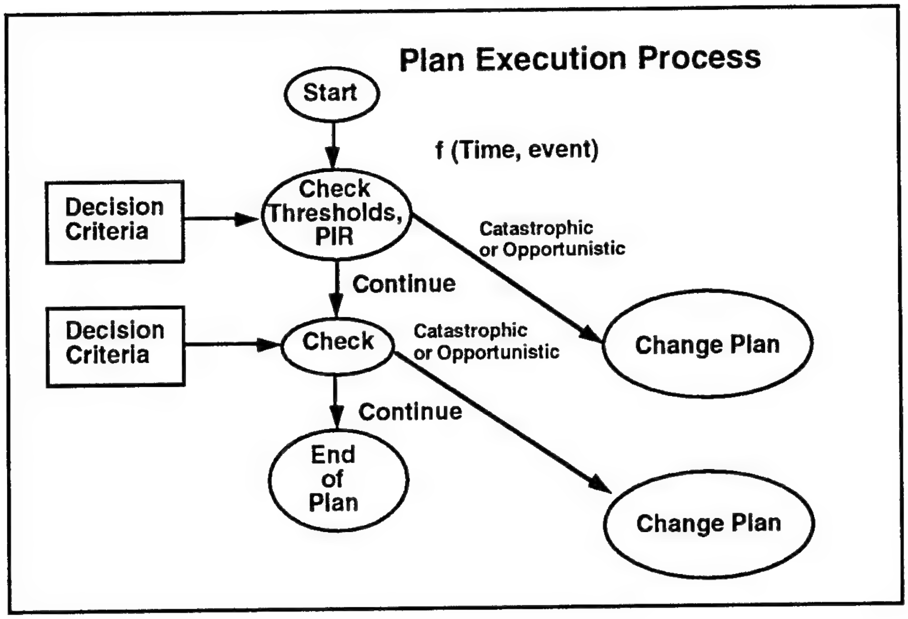

Figure 33—Decision Submodel

Since the most innovative part of this model is the decision submodel, we will explain more about it through an example. The plan includes a set of decision criteria, such as "Withdraw when the force ratio is too high," or "Launch the counterattack when the enemy first echelon is here, and the second echelon is there." The decision criteria include limits and thresholds on various factors, such as friendly and enemy force levels at specific locations and times. Each threshold entails at least one primary information requirement.

When the plan reaches the first decision point, it compares the conditions as perceived in the conflict area to the decision criteria. If the situation exceeds set thresholds, the plan is considered to have failed catastrophically and a new plan is selected. An example of a catastrophic event is that the enemy approached from an unexpected direction. Alternatively, the enemy may have made a mistake, and the plan could recognize that an opportunity exists. This event would also allow for a change of plans.

In most cases, the decision is to continue the plan, since there is apt to be inertia in a corps-sized operation. Unless the situation deviates significantly from the plan, the plan will be followed.

This process is repeated at the next decision point (either time or event driven) until the plan is completed or changed.

```
[ Initially, 204 ACR is in delay mission ]

If Plan-segment of VII-Corps is 1
Then [ 204 ACR falls back after contact with battalion-sized element ]
{
  If prob > 0.3 or [Enemy forces detected by Intel or report of ]
   Referee's Combat-map of our-row, our-col is Yes [204 ACR engaged? ]
  Then
  {
    If prob > 0.3
    Then Log-decision  [Record this event in model's log file]
    "Detected at least 0.05 enemy EDs engaging 204 ACR along path p3"

    Let Time-limit of VII-Corps be Time-in-hours + 2.  [hours]
    Let Plan-segment of VII-Corps be 2.  [Move to next plan segment.]

    If force ratio < 2.0  [Attacker to defender force ratio]
    Then                  [Fight for two hours before withdrawing]
    {
      Exit  [Wait 2 hours, else redeploy immediately ]
    }
```

Figure 34—Decision Model Sample RAND-ABEL Code

This slide shows a sample screen dump of actual code for the dynamic model, which is written in an English-like computer language called RAND-ABEL. Anything between brackets [ ] is considered comment and not executable code. In this example, the 204th ACR will delay and withdraw if engaged by an enemy force at least of battalion size, unless the force ratio is less than 2:1. If it is less than 2:1, the ACR will fight for two hours and then withdraw.

The advantage of the RAND-ABEL language is that it is understandable with some training to most nonprogrammers. Therefore, operational and functional area experts can examine the code for credibility of the plan as well as the intelligence parameters.

In addition, there are no hard-wired numbers in the model. All of the code can be selectively interpreted, even during the middle of a run. Therefore, if one wishes to modify the plan during a model run, one can do so.

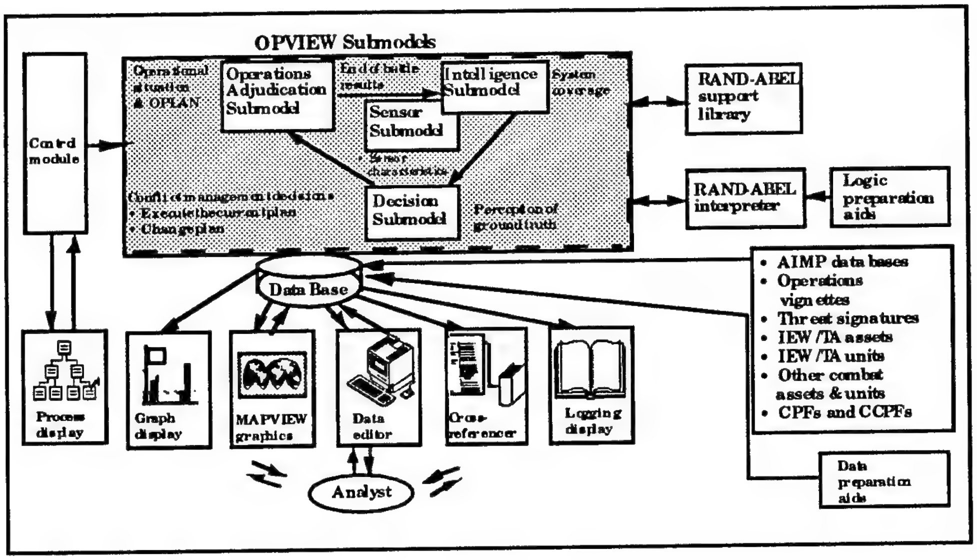

Figure 35—Modeling Environment

To help keep the model development costs down, we chose not to build an entirely new modeling environment. Instead, we took the RAND Strategy Assessment Study (RSAS) model, removed all of the assessment processes and data structure, and retained all of the tools. For example, the RAND-ABEL language, selective interpreter, model log files, data editor, graphics displays, cross reference tools, etc., were kept and a new assessment model (the three submodels described in the shaded area above) was inserted.

In addition, the MAPVIEW graphics display developed for the Theater Level Combat/Non-Linear Combat (TLC/NLC) project was incorporated for graphically displaying the OPVIEW dynamic model outputs.

- Dynamic Model Terrain and Forces
- Dynamic Model Coverage Map Hour 0
- Dynamic Model Coverage Map Hour 4
- Dynamic Model Blue Perceptions Hour 4

Figure 36—Four Sample MAPVIEW Outputs

This chart introduces four figures that illustrate the MAPVIEW outputs of the dynamic model.

After viewing and evaluating these illustrations, the Army Fellows at RAND called our attention to the utility of a collection coverage model for displaying area coverage to aid collection planning and collection management. For example, it would be possible to see at a glance the coverage provided by any single sensor or multiple sensors, by type and quantity.

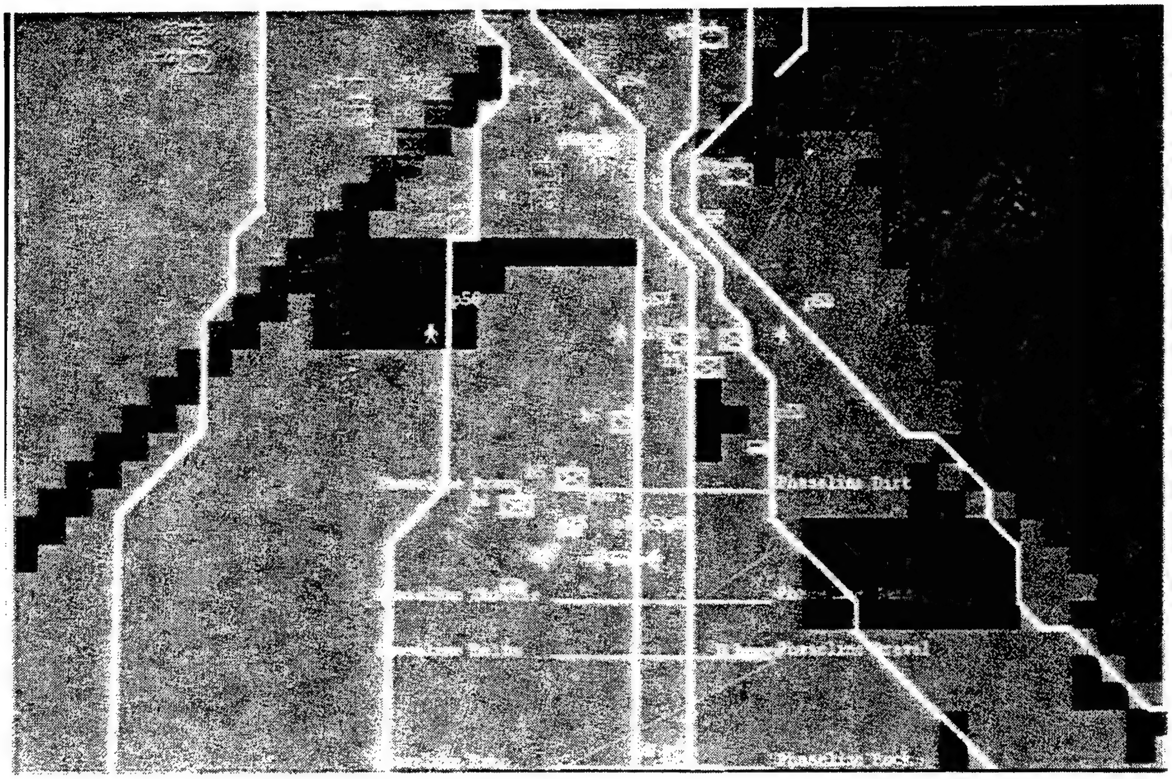

Figure 37—Dynamic Model Terrain and Forces

The scenario is placed in the Kuwait theater of operations (as show above). The dynamic model uses a terrain grid divided into squares 10 kilometers on a side. Water is shown in blue, open terrain is grey, wadi is green, and sandy areas are brown. The white paths are used to help control the movement of units, but units are not restricted to maneuver on the paths. Units can move anywhere on the two-dimensional surface, from the center of any square to the center of any other square. Units may be ordered to follow a path or to move to a square and then follow a path, or vice versa. This is important since if units were restricted only to paths, it would be fairly easy to allocate one's sensors to focus only on the paths. Since units may move anywhere, sensors must be able to cover off-path areas as well.

Operational units in the model are currently resolved at brigade- and regiment-sized units. Types of units include infantry, mechanized, armored, armored cavalry, and artillery. This scenario begins with Iraqi forces crossing through Kuwait, having bypassed some of the Kuwaiti forces. The sensor types represented in this scenario include HUMINT, UAVs, ground-based common sensor (GBCS), SIGINT, GUARDRAIL Common Sensor, ASARS, and JSTARS. The model runs at one-hour time increments, and executes an hour of model time in about 5 minutes.

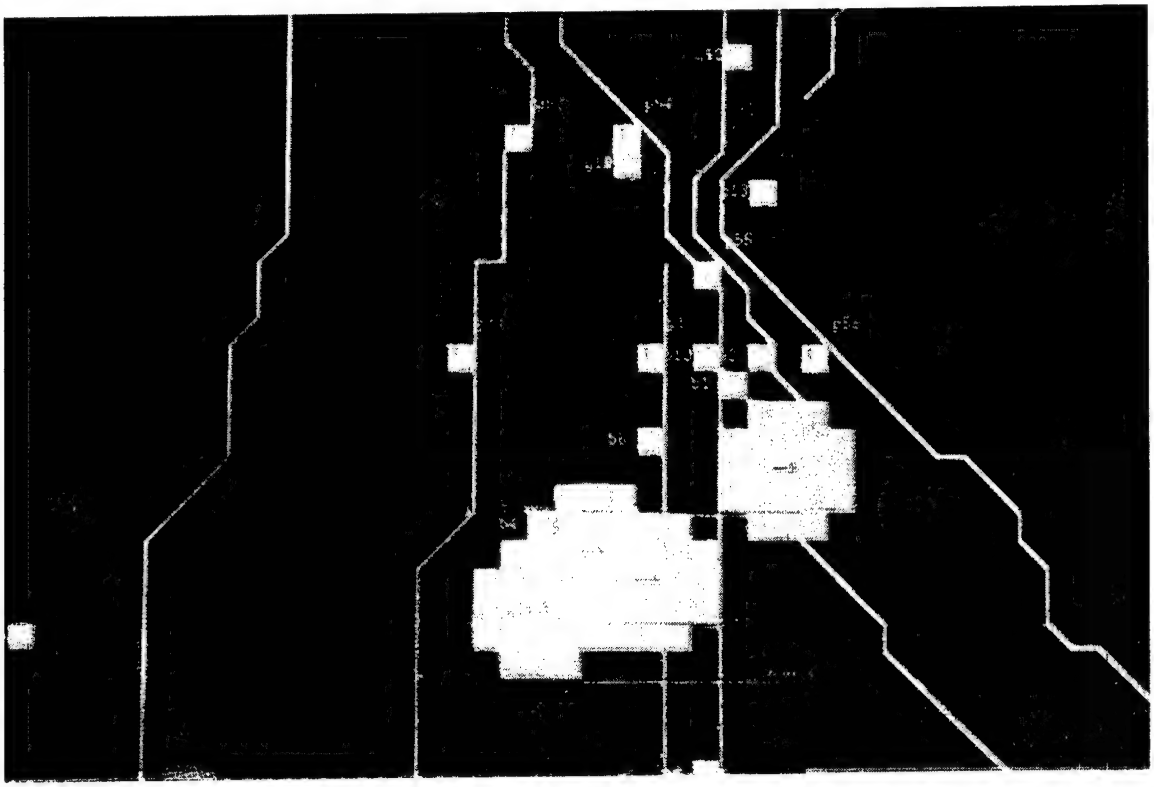

Figure 38—Dynamic Model Coverage Map Hour 0

This map displays the coverage map of Blue sensors at hour zero. The lighter the shade, the higher the detection coverage. A six-shade gray pallet was used, although the degree of coverage (in CCPF) is shown in the model on a scale of 0 to 99.

HUMINT assets associated with operational units and deep HUMINT teams (represented by the figure of a person) can detect fairly well in the terrain grid they occupy. The GBCS (van symbol) can detect very well in its grid square, and to a lesser degree in adjacent squares. The UAVs can detect fairly well in the grid square they occupy, but move around the conflict area more quickly than HUMINT assets.

Off the lower right of the map at an airbase are a JSTARS, an ASARS, and three GRCS. Their coverage is quite extensive and will cover most of the area once these assets reach their orbit locations. In this illustration, this coverage appears as a grey patch in the lower right hand corner of the map. Once these assets are in their orbit locations, it will be more difficult to see the exact coverage of the shorter-ranged collection assets. However, the model accounts for both the area and point detection effects of different types of sensors. Although the CCPFs are calculated separately for each of the eight categories, the coverage map is currently specified only for the detection intelligence category.

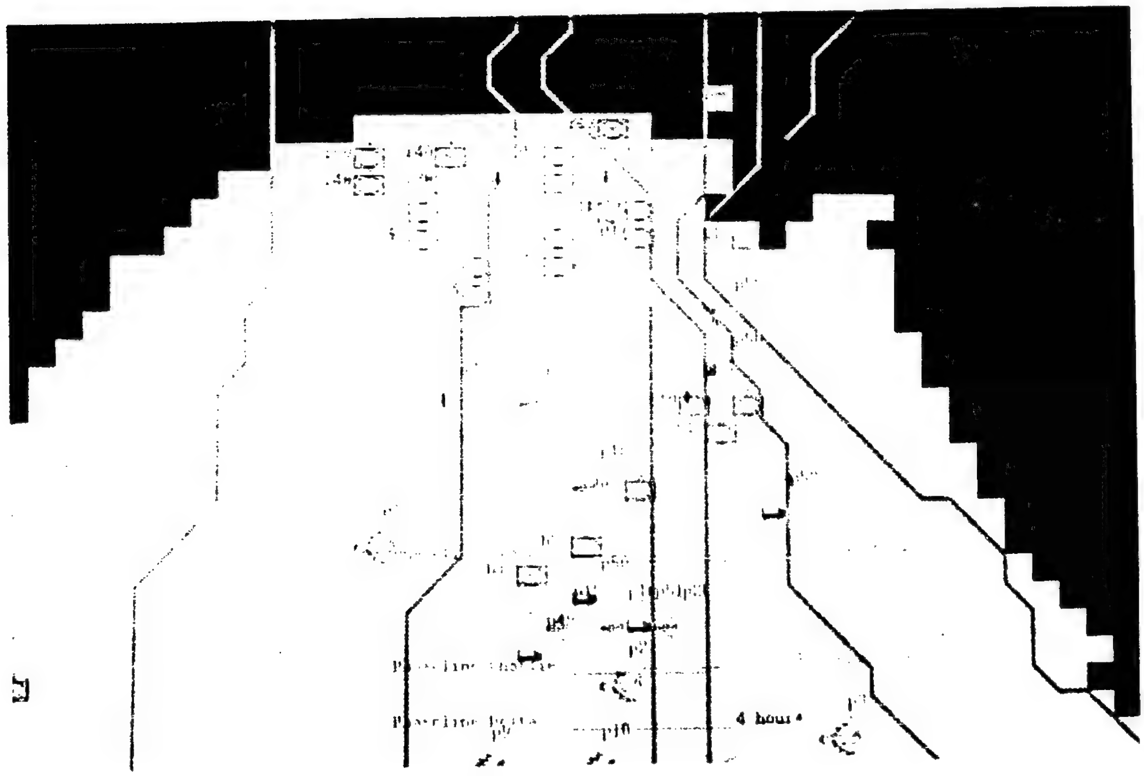

Figure 39—Dynamic Model Coverage Map Hour 4

At hour four, the JSTARS, ASARS, and three GRCS are in their orbit locations (see map above). The coverage map extends far enough to include a large number of enemy units in the "white" region, representing a high degree of coverage. There are other forces in the the light grey area and in the darker grey regions. The model calculates the degree of detection of each enemy unit based upon the types of assets detecting it and the degree of coverage in each of the eight categories.

The UAVs have been launched and are flying to their loiter positions. Multiple loiter positions with different loiter times may be specified to one-hour time periods. The UAV flight paths were designed to penetrate where enemy air defenses are weak, although they will be at risk when flying over or near enemy units..

Attrition of intelligence assets in the model can be deterministic or stochastic. In the stochastic version, a sensor either survives or is killed based upon a random number generator. The higher the enemy active countermeasure threat, and the less survivable the platform, the more likely the platform will be destroyed. In the deterministic version, platforms receive a cumulative percentage damage that proportionally reduces their coverage. The deterministic version represents the average coverage that could be obtained by that sensor over many repetitions.

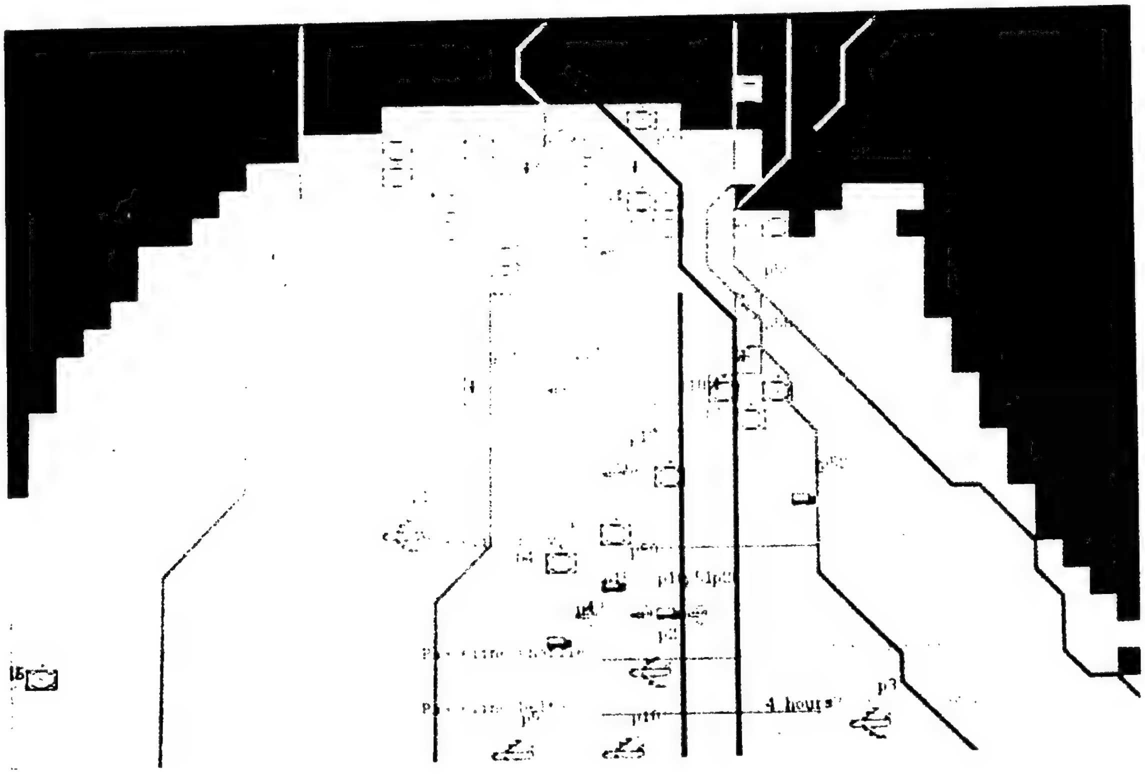

Figure 40—Dynamic Model Blue Perception Hour 4

This map displays the Blue perception of the conflict area at hour four. Note that the identity of the Red units has been removed to reflect the best information currently available on enemy units. For each enemy unit, the model tracks the degree of current coverage in each of the eight intelligence categories, and the types of sensors providing that coverage. An enemy unit can be undetected, whereupon no symbol is shown. If the enemy unit is detected, then only an empty icon is shown. If the unit's size can be determined, then the size symbol is included on the icon. If the type of unit may be determined by the degree of classification coverage, then the type of unit is also displayed (as shown in the figure). If there is sufficient coverage to identify the unit, then the identity of the unit is also displayed.

The decision model uses the perception of the conflict area as the basis for its decisions. The PIRs are also displayed in this picture. The two paths highlighted in Blue indicate that these paths are PIRs for the Blue commander. In addition, five Blue boxes are shown, indicating either named areas of interest (NAIs) or target areas of interest (TAIs). When an enemy unit is attacked in a TAI, the degree of targeting (acquire) coverage is checked. If the targeting coverage is only 50 percent, then at most 50 percent of the target assets could be engaged at that time.

- Methodology
- Static model
- Dynamic model
- Project status and future directions

Figure 41—Outline

This last part of the briefing presents the project's status and future directions.

- Developed a methodology
- Developed static model and prototype dynamic model
  - Static model to be transferred to Army with final report of MI Relook special assistance study
  - Dynamic model to be transferred to the Army with OPVIEW project final report
- Concept for verification and validation of both models provided to the DCSINT
- Use methodology to support a study on IEW contingency operations
  - Apply both models to conduct tradeoff analyses

Figure 42—Project Status

There are three products from the OPVIEW project. The first is a methodology that relates intelligence collection results to commanders' information needs and decisionmaking. The second is a static model to examine a broad range of scenarios at low resolution. The third is a dynamic model to examine a single scenario at increased resolution.

The static model will be transferred to the Army with the final report of the MI 2000 Relook Study. The dynamic model will be transferred to the Army with the OPVIEW project final report.

A concept for verification and validation for both models has been provided to the DCSINT.

We expect to use these three products to perform the MI Look Ahead project, if funded.

- Apply the OPVIEW methodology and appropriate tools (dynamic or static) to an Army and Air Force study in Fiscal Year 1993
  - One prime area of interest is measuring the value of space assets in support of Army and Air Force operations
- Exploit intelligence coverage display technique as a corps and division intelligence planning tool
  - A PC or Mac-based software tool to help intelligence planners and commanders visualize the intelligence coverage of the battlefield over time
  - Exploit the possibility of displaying changes in coverage using the Mac Quicktime movie capability

Figure 43—Future Directions

We plan to apply the OPVIEW methodology and appropriate tools (such as the dynamic and static models) to an Army and an Air Force C3I study during fiscal year 1993. One of the main themes of investigation for each study is measuring the value of space assets for Air Force and Army operations.

A second thrust is the exploitation of the coverage map tools to support intelligence planning in corps and division headquarters. The approach would be to place onto personal computer (PC or Macintosh) software and hardware the coverage map methodology. This would help corps and division intelligence planning and help commanders visualize the intelligence coverage of the battlefield over time. The next slide gives an example of how this type of coverage display might look.

As an extension to the second approach, there is also a "movie" capability for the Macintosh using "Quicktime" software. If this approach is feasible, it may allow a movie of the coverage over time to be made. Such a movie has already been produced from Sun computer outputs displayed on Macintosh terminals. It needs to be determined whether or not this type of display would be feasible for PC or Macintosh coverage map displays.

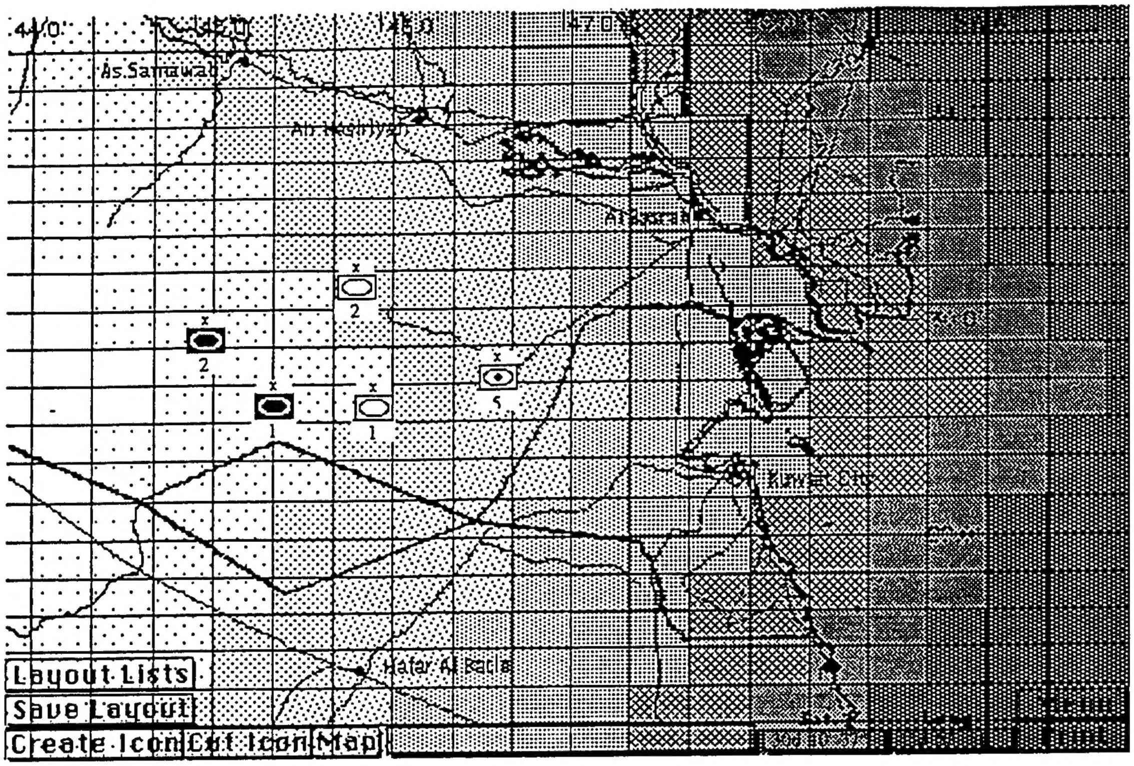

Figure 44—Sample Display of Coverage Planning Tool

In this sample display, there is a background map of the Kuwait theater of operations. The two dark armored units are friendly, while the three light armored and self-propelled artillery units are enemy. The background map and icons were produced by RAND colleague John Wimber on a Macintosh object-oriented software tool known as Hypercard. The coverage overlay was generated from a MicroSoft Excel spreadsheet simulating the dynamic model's coverage calculations and displaying the results on a hypercard display. The dynamic model's coverage map calculations do not yet exist on Excel, so this display simply demonstrates that it is technically feasible to take coverage outputs from an Excel spreadsheet and display them on a hypercard format. Weapons holdings and other descriptors of the units displayed already exist in the Hypercard application, as do the maps of selected areas of the world.